Properties and Processes for Cryogenic Refrigeration

Cryogenic temperatures are required for many technology areas, including infrared sensors for surveillance and atmospheric studies; superconducting electronics, magnets, and power systems; to create clean vacuums in semiconductor fabrication processes; for liquefaction of industrial gas, and many other existing and potential applications. This project addresses issues associated with cryogenic refrigerators, i.e., cryocoolers, and materials performance that are limiting growth in all these technology areas. Proper measurements need to be established to characterize losses within cryocoolers, and models need to be developed to optimize the design of such systems. Material properties data at cryogenic temperatures also are needed by industry for the design of cryogenic equipment, but the data are difficult to find and interpret.

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The layout of our web site has been redesigned to provide clear access to references for the database on cryogenic material properties and to add a graph of each property as a function of temperature between about 4 K and 300 K. The web site is in the process of being updated with many of the graphs being added to materials already on the web site, and we will continue adding new information as it is available.

http://cryogenics.nist.gov/NewFiles/material_properties.html

An invited plenary talk by Ray Radebaugh was presented in August at the 50th anniversary meeting of the Cryogenic Engineering Conference (CEC) on "Applications of Cryogenics in the Last 50 Years." A manuscript of the presentation is a book chapter published in *Advances in Cryogenic Engineering : Transactions of the Cryogenic Engineering Conference* (AIP Conference Proceedings), May 2006.

NIST researchers developed a new measurement method for manufacturers to easily determine the electrical and mechanical losses within pressure oscillators used for Stirling or pulse tube cryocoolers.

In addition, a paper entitled "Evaluation of Pressure Oscillator Losses," was presented by Peter Bradley at the 2005 CEC and is also published in the proceedings (Ref. 3). Measurements of the acoustic impedance of a relatively large (6 mm dia.) inertance tube were made over a range of frequencies, pressures, and reservoir volumes at the end of the inertance tube. Inertance tubes are a component of pulse tube refrigerators that are used to provide the proper flow impedance. The measurements were compared with our transmission line model which had predicted resonance behavior at a particular value of reservoir volume. The measurements were in good agreement with the model. A paper, "Impedance Measurements of Inertance Tubes," presented by Michael Lewis at the 2005 CEC, is in print (Ref. 2). The newly discovered resonance effect that can occur in certain inertance tube/reservoir volume combinations can be useful in decreasing the cooldown time of pulse tube cryocoolers. An invited paper on this possibility was presented at the 8th Annual Directed Energy Symposium in November in which many of the military applications of non-lethal weapons were discussed, some of which require the use of superconductors.

In response to a Defense Advanced Research Projects Agency (DARPA) Broad Area Announcement for proposals for Micro Cryogenic Coolers (MCC) we submitted three proposals in April and received notice in November that we were awarded one of the contracts for the 36-month, two-phase program. We are teamed with the University of Colorado Mechanical Engineering Dept. and the Electromagnetics Division of NIST to develop a mixed-refrigerant Joule-Thomson cryocooler to cool a hot-electron bolometer made of a high-temperature superconductor for terahertz detection. The cooling power is to be 3 mW at 77 K with the total volume less than 4 cm^3.

In the future, we will continue expanding and improving the cryogenic materials database, and developing test methods and improvements in our cryocooler simulation models to address fundamental limitations to the efficiency of cryocooler systems. We will also be working on the miniaturization of cryocoolers with microelectromechanical systems (MEMS) fabrication technology as part of the DARPA program.

References:

1. R. Radebaugh and A. O'Gallagher, ***"Regenerator Operation at Very High Frequencies for Microcryocoolers,"*** *Adv. Cryogenic Engineering,* vol. 51 American Institute of Physics; 1 edition (May 2006), p. 1919.
2. M.A. Lewis, P.E. Bradley, R. Radebaugh, and E. Luo, ***"Impedance Measurements of Inertance Tubes,"*** *Adv. Cryogenic Engineering,* vol. 51, American Institute of Physics; 1 edition (May 2006), p. 1557.
3. P.E. Bradley, M.A. Lewis, and R. Radebaugh, "**Evaluation of Pressure Oscillator Losses**," *Adv. Cryogenic Engineering,* vol. 51, American Institute of Physics; 1 edition (May 2006), p. 1549.